Irish Journal of Agricultural and Food Research **48:** 75–86, 2009

Prediction of cull cow carcass characteristics from live weight and body condition score measured pre slaughter

W. Minchin[1,2], F. Buckley[1], D.A. Kenny[2], M.G. Keane[3], L. Shalloo[1] and M. O'Donovan[1]†

[1]*Moorepark Dairy Production Research Centre, Teagasc, Moorepark, Fermoy, Co. Cork, Ireland*
[2]*School of Agriculture, Food Science and Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland*
[3]*Teagasc, Grange Research Centre, Dunsany, Co. Meath, Ireland*

A study was conducted to provide information on the degree of carcass finish of Irish cull cows and to investigate the usefulness of live animal measurements for the prediction of cull cow carcass characteristics. Live weight (LW) and body condition score (BCS) were recorded on cows entering an Irish commercial slaughter facility between September and November, 2005. Data pertaining to sire breed, age and carcass characteristics were collected and subsequently collated for each cow. For analysis, cows (n = 2163) were subdivided into three breed categories: dairy breed sired by Holstein/Friesian (FR), sired by early-maturing beef breeds (EM) and sired by late-maturing beef breeds (LM). The proportion of cows slaughtered at the desired (TARGET) carcass standard (cold carcass weight ≥ 272 kg, carcass conformation class ≥ P+ and carcass fat class ≥ 3) was low (on average 0.30), but did differ ($P < 0.001$) between the dairy and beef breed categories (0.22, 0.47 and 0.53 for FR, EM and LM categories, respectively). Regression procedures were used to develop equations to predict cold carcass weight, carcass conformation score, carcass fat score and proportion in the TARGET category from LW and BCS. Equations predicting cold carcass weight had high R^2 values for all breed categories (0.81, 0.85 and 0.79 for the FR, EM and LM, respectively). Equations predicting carcass fatness had moderate R^2 values for the beef breed categories (0.65 and 0.59 for the EM and LM, respectively). Equations predicting carcass conformation and the TARGET category yielded lower R^2 values. The successful prediction of carcass weight for all breed categories and of carcass fatness for the

†Corresponding author: michael.odonovan@teagasc.ie

beef breeds (albeit with a moderate R^2 value compared to the carcass weight prediction) using objective, non-intrusive and easily measured live animal measurements, should be of benefit to farmers finishing cull cows in Ireland.

Keywords: animal measurements; carcass characteristic; cull cows; predictive equations

Introduction

As the majority of beef produced in Ireland is destined for export, the objective should be to produce lean carcasses of good conformation suitable for the highest priced markets, which are in continental Europe (Drennan and Keane, 2000). Compared with 2005, cow numbers slaughtered increased in 2006 by 5% to 363,200 (DAF, 2006) and accounted for 22% of the total number of animals slaughtered in that year. Strategies to improve cull cow carcass value could significantly improve the financial return from cull cows. Despite market price differentials and descriptions of desirable cow beef conformation class (Klosterman, 1972), the effect of the differences among breeds on live and carcass characteristics under seasonal pasture-based systems has received inadequate attention. This is particularly true for cull dairy cows. It has been demonstrated that increasing the plane of nutrition of cull beef (Brown and Johnson, 1991) and dairy (Minchin *et al*., 2009a) cows before slaughter improves carcass characteristics. Studies describing the degree of carcass finish in the national cull cow population, however, have not been conducted. Hence, the degree to which the profit margin of dairy or beef enterprises may be increased by improvements in cull cow carcasses needs to be established.

It would be desirable if farmers could determine from pre-slaughter measurements when animals are suitable for slaughter. Research to date on predicting optimum finish criteria for cows has been of limited value due to variability (breed, age and animal measurements) between studies (Dolezal, Tatum and Williams, 1993). While an array of techniques (ultrasound technology, height, heart girth and length) have been developed to predict carcass quality for growing prime cattle, all have limited application to mature cull cows (Gresham *et al*., 1986). Previous authors have examined the development of prediction equations (Hedrick, 1983; Perry and Fox, 1997) where carcass traits can be estimated from an index or series of indices, in an attempt to minimise the economic loss associated with failing to achieve acceptable standards of finish. If value-based marketing (Drennan, McGee and Keane, 2008) is to become a reality for the beef industry, an accurate method for estimating body composition of live cows is essential (Herring *et al*., 1994). Many authors have used ultrasonic measurement of fat in their prediction equations (Wallace *et al*., 1977; Anderson *et al*., 1983; Herring *et al*., 1994) but the practicality of ultrasonic measurement at farm level is questionable in terms of availability and cost. There is a need to develop prediction equations for cull cow carcass composition using independent variables that are repeatable, non-intrusive and easily measured at farm level (Hedrick, 1983). Obvious examples include live weight (LW) and body condition score (BCS).

The objectives of this study, therefore, were: (i) to ascertain the degree of carcass finish of cows slaughtered off Irish farms at the end of the grazing season and (ii) to develop prediction equations for carcass weight, carcass conformation, carcass fatness and for the attainment of desired carcass standard, based on cold carcass weight, conformation and fatness, using pre-slaughter measurements

Materials and Methods

Experimental approach
Data used in this study were obtained from 2,163 cows measured in a commercial slaughter facility between September and November, 2005. The dataset represented cull cows from a broad range of farms in the south of Ireland and was typical of the normal cull cow kill at the particular slaughter facility. Live weight and BCS were recorded on cows entering the slaughter facility by the same trained evaluator during 25 visits. Live weight was recorded electronically, using portable weighing scales and the Winweigh software package (Trutest limited, Auckland, New Zealand). The scales were calibrated weekly against permanent scales at the Moorepark Dairy Production Research Centre and were calibrated again with known weights on each day of the study. Body condition score was assessed using a five point linear scale (1 = emaciated, 5 = extremely fat) with increments of 0.25 (Lowman, Scott and Somerville, 1976). These measurements were recorded in a restraining compartment just prior to the slaughter crate. Cows were identified by their unique national identification number (DAF, 2006). Details pertaining to animal identification, herd number, breed (of sire) and birth date were obtained from the Irish cattle movement monitoring system (Cattle Movement Monitoring System – CMMS, 2006) for each cow.

Carcass traits
Carcass data were collected after slaughter, including cold carcass weight (left plus right sides), carcass conformation class and carcass fat class. Kill-out proportion was calculated as the ratio of cold carcass weight to pre-slaughter LW. Carcass conformation and fat classes were assessed according to the EU Beef Carcass Classification Scheme (Commission of the European Communities, 1982) by video image analysis (Allen, 2003). Each of the 5 classes was sub divided into 3 and each sub class was awarded a score on a 1 to 15 scale (15 = best conformation class and highest fat class).

Data editing
The animals were assigned to one of three breed categories for analysis: cows with Holstein/Friesian sires (FR), cows with sires of early-maturing (EM) beef-breeds (Hereford, Angus and Shorthorn) and cows with sires of late-maturing (LM) beef-breeds (Charolais, Limousin, Simmental and Belgian Blue). No attempt was made to differentiate between pure-bred and crossbred cows, but the vast majority of the beef breed cows would have been crossbred, based on the breed composition of the Irish cattle population (CMMS, 2006). Animals sired by dual purpose breeds (Ayrshire, Montbelliarde, Normande and Rotbunte) or minor beef breeds (Salers, Blonde D'Aquitane, Piedmontese, etc.) were excluded from all analyses because of insufficient numbers. The number and overall proportion of animals are presented in Table 1 for each sire breed. The dairy (FR), early-maturing beef breed (EM) and late-maturing beef breed (LM) categories accounted proportionately for 0.67, 0.15 and 0.18 of the total, respectively.

In order to obtain maximum carcass value per unit carcass weight, Irish commercial slaughter facilities impose minimum carcass weight, carcass conformation and carcass fat class criteria. In the case

Table 1. Number and proportion of animals in each breed category

Breed category	Number	Proportion
Dairy sires (FR)		
Holstein/Friesian	1441	0.666
Early-maturing beef sires (EM)		
Angus	80	0.037
Hereford	218	0.101
Shorthorn	38	0.018
Late-maturing beef sires (LM)		
Belgian Blue	32	0.015
Charolais	131	0.061
Limousin	127	0.059
Simmental	96	0.044

of the slaughter facility involved in the current study these criteria were: cold carcass weight ≥ 272 kg, carcass conformation class of P+ or better (= 3 on the 15 point scale), and carcass fat class ≥ 3 (= 7 on the 15 point scale). Failure to achieve the desired threshold for either cold carcass weight, conformation class or fat class by one increment (1 kg, one conformation class or one fat class) resulted in a reduced payment of approximately €0.04/kg, €0.04/kg and €0.13/kg, respectively, assuming the other criteria were achieved. Failure to achieve all three criteria simultaneously resulted in a €0.42/kg reduction in carcass value regardless of the discrepancy between the target criteria and actual performance (DAF, 2006). A binary trait, denoted as TARGET, was created to indicate success (1) or failure (0) of each carcass to meet all three quality criteria.

Statistical analysis

Data were analysed using the Proc GLM of SAS (SAS, 2002). Each model included breed category as a fixed effect with age in months as a covariate. The variation due to breed category was partitioned into two single-degree-of-freedom orthogonal contrasts (Snedecor and Cochran, 1980). These contrasts were: (i) the difference between the FR and LM + EM, and (ii) the difference between the LM and EM breed categories. The proportion of cows achieving the TARGET carcass across a range of LW and BCS categories were compared using chi square.

The regression procedure within Proc REG (SAS, 2002) was used to determine prediction equations for cold carcass weight, carcass conformation score, carcass fat score and TARGET carcass using LW and BCS as independent variables. In total, 12 equations were generated; 4 carcass variables (cold carcass weight, conformation score, fat score and TARGET carcass) by 3 breed categories (FR, EM, LM).

Data on cull cows (n = 124) from 2 finishing experiments conducted by Minchin *et al*. (2009a,b) were used to validate the prediction equations for cold carcass weight within the FR category. A regression analysis (Proc REG of SAS) was used to evaluate the association between predicted and observed cold carcass weight. Residuals were calculated for the validation data set as the difference between the observed (true) carcass weight and the predicted carcass weight. Criteria used to assess (validate) the predictive ability of the equation included: normality of the residuals, the average bias (mean of the residuals), the root mean square error (standard deviation of the residuals) and the accuracy of fit defined as the variance of observed carcass weight divided by the sum of the variance of observed carcass weight plus the variance of the residuals. Due to the small number of animals and the variable breed content it was considered not feasible to use a sample of the available data (MacNeil, 1983) for validation purposes.

Results

Live and carcass traits

Least squares means for live and carcass measurements together with significance of orthogonal contrasts are shown in Table 2. Age at slaughter did not differ significantly amongst the breed categories. Average cold carcass weight was above the specified threshold for all breed categories. Kill-out proportion was greater (P < 0.001) for the EM plus LM categories than for the FR category and greater (P < 0.001) for LM than EM. Cows in the FR category, on average, were slaughtered below the specified carcass fat score threshold of 7 and were also marginally below the desired carcass conformation score threshold of 3. On average, both the EM and LM categories were slaughtered at values for carcass weight, conformation and fatness to achieve the TARGET in about 50% of cases. The TARGET was achieved by a greater (P < 0.001) proportion of the EM plus LM categories than the FR category while the proportion achieving the TARGET did not differ between the EM and LM categories.

Compared to the FR category, the EM plus LM categories were slaughtered at a lower LW (P<0.05) and higher BCS (P<0.001). The EM plus LM categories had higher cold carcass weight (P<0.001), higher carcass conformation (P<0.001) and fat score (P<0.001) values and higher kill-out proportion (P<0.001) than the FR category. The LM category was slaughtered at a heavier LW (P<0.001) than the EM category. Both EM and LM categories were slaughtered at a mean BCS of 3.3. Cold carcass weight, carcass conformation score and kill-out proportion were greater (P<0.001) for the LM than the EM category, while carcass fat score was greater for the EM than the LM breed category.

Influence of LW and BCS on achievement of TARGET specification

The proportion of cows achieving the TARGET for a range of LW and BCS combinations is presented in Table 3 for each breed category. As both LW and BCS increased, the proportion of cows meeting the TARGET tended to increase for all breed categories. Only 2%

Table 2. Least square mean values (s.e.) for live and carcass measurements of cull cows together with orthogonal contrasts

	Breed category[1]			Contrasts	
	FR	EM	LM	FR *v* EM + LM	EM *v* LM
Age at slaughter (months)	98 (0.7)	102 (1.4)	100 (1.3)		
Live weight (kg)	587 (2.2)	564 (4.6)	591 (4.2)	*	***
Body condition score[2]	3.0 (0.01)	3.3 (0.03)	3.3 (0.03)	***	
Cold carcass weight (kg)	277 (1.4)	278 (2.9)	301 (2.6)	***	***
Carcass conformation score[3]	2.9 (0.04)	4.3 (0.09)	4.9 (0.08)	***	***
Carcass fat score[4]	5.8 (0.09)	8.3 (0.18)	7.4 (0.16)	***	**
Kill-out proportion	0.47 (0.001)	0.49 (0.003)	0.51 (0.003)	***	***
TARGET[5]	0.22 (0.012)	0.47 (0.024)	0.53 (0.022)	***	

[1] FR = sired by Holstein-Friesian; EM = sired by early maturing beef breeds (Angus, Hereford, Shorthorn); LM = sired by late maturing beef breeds (Charolais, Limousin, Simmental, Belgian Blue).
[2] On scale 1 to 5 as per Lowman, Scott and Somerville (1976).
[3] Scale 1 to 15 (15 = best conformation; EUROP conformation scale).
[4] Scale 1 to 15 (15 = fattest; EUROP fat scale).
[5] TARGET = 1 when carcass weight ≥ 272 kg, carcass conformation score ≥ 3 and carcass fat score ≥ 7, otherwise = 0.

Table 3. Proportion of cows within breed category[1] (FR, EM and LM) achieving the TARGET[2] specification values for various combinations of live weight and body condition score (BCS)

BCS (1 to 5 scale)	Live weight (kg)		
	< 550	550–620	> 620
		FR category	
≤ 3.00	0.02 (0.019)[3] (n = 414)[4]	0.11 (0.024) (n = 267)	0.35 (0.037) (n =109)
3.25	0.20 (0.061) (n = 40)	0.32 (0.040) (n =92)	0.44 (0.031) (n = 154)
≥ 3.50	0.29 (0.093) (n = 17)	0.41 (0.040) (n = 93)	0.40 (0.024) (n = 255)
		EM category	
≤ 3.00	0.01 (0.030) (n = 94)	0.17 (0.060) (n = 23)	0.00 (0.143) (n = 4)
3.25	0.17 (0.058) (n = 24)	0.40 (0.064) (n = 20)	0.56 (0.095) (n = 9)
≥ 3.50	0.41 (0.044) (n = 42)	0.98 (0.042) (n = 46)	0.99 (0.033) (n = 74)
		LM category	
≤ 3.00	0.03 (0.036) (n = 92)	0.18 (0.056) (n = 36)	0.31 (0.095) (n = 11)
3.25	0.25 (0.099) (n = 10)	0.52 (0.061) (n = 29)	0.77 (0.073) (n = 20)
≥ 3.50	0.35 (0.071) (n = 21)	0.90 (0.049) (n = 46)	0.90 (0.031) (n = 121)

[1,2] See footnote to Table 2.
[3] s.e.
[4] Number of animals.

of the carcasses from FR cows slaughtered at low LW (< 550 kg) and low BCS (< 3.25) achieved the TARGET specification. Approximately 40% of the carcasses from FR cows slaughtered at LW ≥ 550 kg with a BCS ≥ 3.5 achieved the TARGET specification, while a high proportion (0.90 or greater) of carcasses from cows in the EM and LM categories slaughtered at the same combination of weight and BCS achieved the TARGET specification.

Prediction equations

The "best" prediction equations for carcass weight, carcass conformation score, carcass fat score and TARGET for each of the three breed categories are presented in Table 4. For cold carcass weight, both LW and BCS were significant for all breed categories and the highest coefficients of determination were obtained when these were included in the model. LW was not a significant predictor of carcass conformation score or carcass fat score for any of the breed categories and BCS was not significant for FR. BCS did contribute significantly to the prediction of carcass conformation score (R^2 0.49 and 0.43) and carcass fat score (R^2 0.65 and 0.59) for EM and LM. Both LW and BCS contributed significantly to the prediction of TARGET for all three breed categories but the coefficient of determination of the prediction equation for FR was considerably lower than for the two beef breed categories. For both the EM and LM categories, the predicted equations for TARGET resulted in moderate R^2 values.

Validation of predictions

Figure 1 shows the relationship between actual and predicted cold carcass weight, using live animal and carcass records from Minchin *et al*. (2009a,b), for FR type cows. The high coefficient of determination indicates that the equation predicted differences in cold carcass weight quite well for the independent data set. The prediction equation resulted in a significant bias of 18 (s.e. 1.14) kg. The correlation between the observed carcass weight and the residuals was not different from zero indicating that the deviation between actual and predicted values did not vary across the entire validation data set.

Discussion

Animal production decision-making is becoming more complex. The Luxembourg Agreement (Council of the European Union, Luxembourg Agreement, 2003)

Table 4. Prediction equations, using live weight (LW) and body condition score (BCS) as predictors, for four dependent variables and three breed categories

Carcass trait	Breed category[‡]	Intercept	Regression coefficients for		√Mean squared error	R^2
			LW (kg)	BCS[†]		
Cold weight (kg)	FR	−48.89***	0.34***	41.90***	2.21	0.81
	EM	−71.80***	0.38***	40.72***	21.49	0.85
Conformation score	LM	−74.56***	0.41***	40.38***	26.57	0.79
	FR	2.94***	–	0.04	1.49	0.00
	EM	−2.79***	–	2.14***	1.16	0.49
Fat score	LM	−3.33***	–	2.50***	1.42	0.43
	FR	5.44***	–	0.11	3.21	0.00
	EM	−8.70***	–	5.12***	1.98	0.65
TARGET carcass	LM	−9.60***	–	5.16***	2.10	0.59
	FR	−0.91***	0.001***	0.18***	0.39	0.15
	EM	−1.99***	0.002***	0.48***	0.35	0.52
	LM	−2.02***	0.002***	0.45***	0.36	0.48

[‡,†] See footnotes to Table 2.

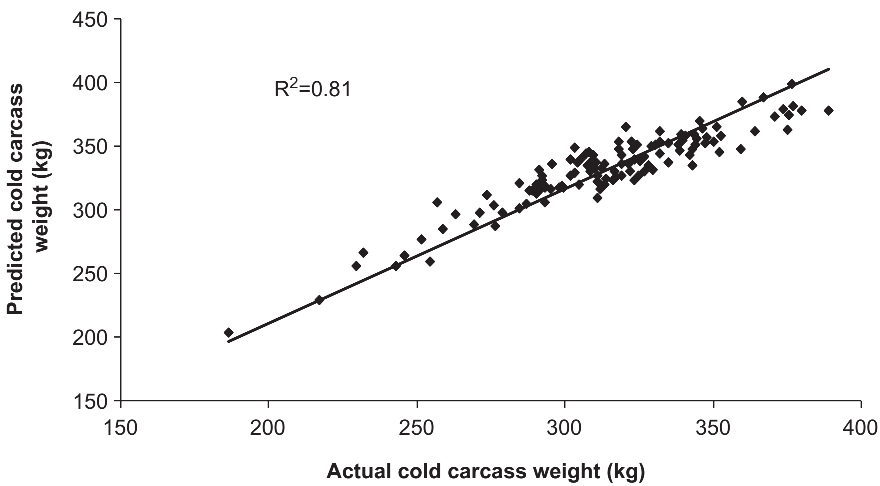

Figure 1. Validation of the cold carcass weight prediction using actual data (n = 124) from slaughtered cull dairy cows (predicted cold carcass weight as per equation in Table 4 for FR category).

moved farm supports from product specific payments to a single farm payment based on historical (2000 and 2001) farm support payments and area farmed (Crosson *et al*., 2006). This reform returned the focus of producer decisions to market-based considerations thereby reducing the distortions that have been caused by headage-based livestock subsidies (Van Arendonk, 1985). Hence, there is an increasing need to manage the way information is combined and used when making farm decisions to enhance the efficiency of production systems.

It is clear from the results that the practice of finishing cull cows is not consistent across dairy and beef herds. Cows are being presented for slaughter with carcasses that range from grossly under finished to exceptionally well finished. The present results show that only a minority of cows slaughtered between late September and late November achieved the carcass specification that maximised value per unit weight. The proportion of the culled dairy (FR) cows achieving the TARGET was 0.22, while that for the beef (EM and LM) cows averaged 0.50. In the case of FR, it can be assumed that at least 55% of cull cows did not receive any special finishing treatment prior to slaughter based on their pre-slaughter BCS of ≥ 3. On the other hand, it is plausible to suggest that approximately 25% (slaughtered at a BCS ≥ 3.5) were subjected to some form of finishing treatment. Of the latter, however, proportionately only 0.40 managed to achieve the TARGET, suggesting either a limitation on the part of FR-sired animals to achieve the TARGET, or that the degree of finish achieved was insufficient. Recent studies by Minchin *et al.* (2009a,b) demonstrated that the majority of FR cows offered a range of finishing diets were capable of successfully attaining the maximum value per unit carcass weight. Nevertheless, Holstein-Friesian sired cattle are inferior to those sired by beef breeds with respect to carcass conformation (Keane, 1994; Keane, 2003; Keane and Drennan, 2008). The current data reveal that of the dairy cows slaughtered at a BCS ≥ 3.5 and failing to achieve the TARGET carcass, more than 60% failed to achieve the carcass conformation threshold. Approximately 50% of the beef cows were slaughtered at a BCS ≥ 3.5. Of those with a pre-slaughter live weight of ≥ 550 kg, over 90% attained the maximum carcass value per unit weight. This further emphasises the innate differences in beef characteristics that exist between cattle sired by beef and dairy breeds. Beef breed comparisons generally show that the late-maturing European continental breed types have superior carcass conformation, kill-out proportion and a higher muscle-to-fat ratio compared to early-maturing British breed types (Kempster, Cook and Southgate, 1982; Southgate, Cook and Kempster, 1982; Keane and Drennan, 2008). In the present study, the LM category was superior to the EM category for cold carcass weight, carcass conformation score and kill-out proportion, and had a lower carcass fat score. This finding is typical of beef breed comparisons. The EM animals mature at a lower LW, have smaller skeletal size and require a shorter finishing period (Keane and Drennan, 2008). Despite being easier to finish, it appears that at least 36% of beef-sired cull cows in the present study received no particular finishing treatment prior to slaughter because they had a pre-slaughter BCS ≤ 3.

It was not possible to determine if all cows in the present study that were slaughtered unfinished could have been profitably finished. However, it would appear that the potential exists to significantly increase the profit margin from such cows. The dairy cows in the current study that were deemed to have not been subjected to a finishing regime (BCS ≤ 3) yielded carcasses with a mean cold weight of 245 kg, a mean conformation score of 3, and a mean fat score of 6. At current prices, carcasses of this type would be expected to be worth approximately €448 each (DAF, 2008). The price expected for a carcass just meeting the TARGET criteria is €745. The under-finished (BCS <3) FR cows in the present study are comparable to cows slaughtered without finishing in the study of Minchin *et al.* (2009b) which had the following carcass traits: cold carcass weight 251 kg, carcass conformation class 2 and carcass fat class 3. Minchin *et al*. (2009a) demonstrated that cull dairy cows starting from this point could be finished to the TARGET specification by utilizing 1.5 t DM of high quality (72 dry matter digestibility) grass silage, valued at €130 t (Teagasc, 2007). If the mean carcass values of the FR category are compared to the TARGET, a difference in carcass value of approximately €238 would be expected. Considering their moderate BCS, it is expected that these cows might have finished in 60 days, utilizing 0.75 t of grass silage (valued at €97.50). Thus, it would appear there is potential for a considerable increase in profit margin per cow. It is acknowledged, however, that the profitability of cull cow finishing depends greatly on the prevailing market conditions: purchase and sale prices, and costs of feed, housing and labour.

Prediction equations

The traits used in the prediction equations (LW and BCS) were simple, accurate and non-invasive indicators of carcass weight, but they were less accurate indicators of carcass classification. Previous studies have evaluated the use of ultrasound techniques as a method to predict carcass composition in live animals (Smith *et al*., 1989; Stouffer, Perry and Fox, 1989). While prediction equations using ultrasound accounted for a large proportion of variation, the practicality of applying these measurements at farm level is limited by issues such as cost of equipment and operator reliability (Houghton and Turlington, 1992). The relationship of muscular and skeletal scores, recorded on live animals, with carcass composition and value in steers and heifers were examined in a recent Irish study and it was concluded that live animal muscular scores are useful indicators of carcass meat proportion and value (Drennan and Conroy, 2008). The current study illustrates that LW and BCS vary in their usefulness for the prediction of cold carcass weight, carcass conformation score, carcass fat score and TARGET. While, the ability to predict cold carcass weight from LW and BCS was consistent regardless of breed category, the prediction equations for carcass conformation score, carcass fat score and TARGET provided moderate to poor outcomes, so in essence are deemed not to be useful in practice. Kress, Hauser and Chapman (1969), Heinrichs, Rogers and Cooper (1992), Thompson *et al*. (1983) and Fiems *et al*. (2005) compared several combinations of variables to estimate empty body fat. Nelson *et al*. (1985) concluded no one method could be judged the "correct" method, until comparisons are made over a wide range of genotypes of cattle of various body condition scores.

With regard to the validation exercise, a high precision of prediction was obtained but the equation over-predicted cold carcass weight by on average 18 kg, which represents approximately 5% of the observed value, and may be attributable to LW losses associated with transport to the slaughter facility. The animals used for the validation data set (Minchin *et al*., 2009a,b) were weighed at the Moorepark Research Centre prior to being transported to slaughter, and thus were subject to gut fill losses between recording of live weight and slaughter. Furthermore, animals are commonly held for a variable period, without feed, in the lairage prior to slaughter. Gut fill loss can amount to approximately 7% of LW (Earley *et al*., 2004) depending on trip duration and hours to slaughter from final feeding. It is important that this bias is taken into consideration if the current equation is used in practice. The coefficients of determination obtained for the prediction of carcass conformation score, carcass fat score and TARGET were not satisfactory and therefore validation was not considered worthwhile. Data were not available to validate the equations for the beef categories.

It is important that prediction equations can be easily applied at farm level. One potential drawback is the fact that weighing scales are not routinely available on Irish beef farms. Heart girth has been shown previously to be strongly correlated with LW (Nelson *et al*., 1985) and could be used as an alternative. This needs validation, but would offer improved applicability at farm level.

Age at slaughter

A noteworthy observation was the small differences in mean age amongst the breed categories. Prior to conducting the study, age at slaughter was expected to be lower for dairy cows than for beef cows due to the well documented issue of poorer fertility/longevity of Holstein-Friesian dairy cows (Evans *et al*., 2004). Esselmont and Kossaibati (1997) found that 41% of dairy cows were slaughtered by the end of third lactation, while Sol, Stelwagen and Dijkhuizen (1984) reported an average culling age of 5.7 years (fourth lactation) for dairy cows. In the present study the mean age at slaughter for all cows was 8.2 years (sixth lactation). It is likely that a disproportionate number of older dairy cows are slaughtered during the autumn/winter period at the end of lactation. This may occur because older cows are more difficult to finish (Minchin *et al*., 2009a; Sawyer, Mathis and Davis, 2004). It is reasonable to suggest that younger cows may be held back to finish for slaughter in spring, which generally coincides with peak cow-beef price. Alternatively, younger cows may be sold to specialised finishing units, retained and recycled within the dairy enterprise.

Live weight and BCS are useful predictors of cold carcass weight but are of limited value for prediction of conformation or fatness.

References

Anderson, B.B., Busk, J., Chadwick, J.P., Cuthbertson, A., Fursey, G.A.J., Jones, D.W., Lewin, P., Miles, C.A. and Owen, M.G. 1983. Comparison of ultrasonic equipment for describing beef carcass characteristics in live cattle (report on a joint ultrasonic trial carried out in the U.K. and Denmark). *Livestock Production Science* **10:** 133–147.

Allen, P. 2003. Beef carcass grading in Europe and USA – The prospects for using VIA systems. *Brazilian Journal of Food Technology* **6:** 96–101.

Brown, W.F. and Johnson, D.D. 1991. Effects of energy and protein supplementation of ammoniated tropical grass hay on the growth and carcass characteristics of cull cows. *Journal of Animal Science* **69:** 348–357.

Cattle Movement Monitoring System. 2006. CMMS statistics report, Irish Bovine Animal Identification and Tracing System. The Department of Agriculture and Food, Dublin, Ireland.

Commission of the European Communities. 1982. *European Communities (Beef Carcass Classification) Regulations*. Council Regulations 1358/80, 1208/81, 1202/82. Commission Regulation Regulations 2930/81, 563/82, 1557/82.

Council of the European Union. 2003. "CAP Reform-Presidency Compromise (in agreement with the Commission)", Brussels, June 2003.

Crosson, P., O'Kiely, P., O'Mara, F.P. and Wallace, M. 2006. The development of a mathematical model to investigate Irish beef production systems. *Agricultural Systems* **89:** 349–370.

DAF (Department of Agriculture and Food). 2006. CMMS (Cattle movement monitoring system), CMMS statistics report 2006. www.agriculture.gov.ie

DAF. 2008. (Department of Agriculture and Food) CMMS (Cattle Movement Monitoring System), CMMS Statistics Report 2006. www.agriculture.gov.ie

Dolezal, H.G., Tatum, J.D. and Williams, Jr. F.L. 1993. Effects of feeder cattle frame size, muscle thickness, and age class on days fed, weight, and carcass composition. *Journal of Animal Science* **71:** 2975–2985.

Drennan, M.J. and Conroy, S. 2008. "Beef prices must reflect carcass quality", Teagasc, Grange

Beef Research Centre Beef Open Day Booklet, 8 May 2008. www.agresearch.teagasc.ie/grange/openday2008/index.htm, pages 22–23.

Drennan, M.J. and Keane, M.G. 2000. Breeding quality cattle for Europe. *Irish Grassland and Animal Production Association Journal* **34:** 100–104.

Drennan, M.J., McGee, M. and Keane, M.G. 2008. The value of muscular and skeletal scores in the live animal and carcass classification scores as indicators of carcass composition in cattle. *Animal* **2:** 752–760.

Earley, B., Fisher, A., Farrell, J.A., Murray, M., Nolan, M., Prenderville, D. and O'Riordan, E.G. 2004. Effects of pre-journey fasting on the physiological responses of young cattle to 8-hour road transport. Beef Production Series No. 62, Grange Research Centre, Dunsany, Co. Meath. ISBN 1 84170 357 5, 36 pages.

Esselmont, R.J. and Kossaibati, M.A. 1997. Culling in 50 dairy herds in England. *Veterinary Record* **140:** 36–39.

Evans, R.D., Dillon, P., Shalloo, L., Wallace, M. and Garrick, D.J. 2004. An economic comparison of dual-purpose and Holstein-Friesian cow breeds in a seasonal grass-based system under different milk production scenarios. *Irish Journal of Agricultural and Food Research* **43:** 1 – 16.

Fiems, L.O., Van Caelenbergh, W., Vanacker, J.M., De Campeneere, S., Seynaeve, M. 2005. Prediction of empty body composition of double-muscled beef cows. *Livestock Production Science* **92:** 249–259.

Gresham, J.D., Holloway, J.W., Butts, Jr. W.T. and McCurley, J.R. 1986. Prediction of mature cow carcass composition from live animal measurements. *Journal of Animal Science* **63:** 1041–1048.

Hedrick, H.B. 1983. Methods of estimating live animal and carcass composition. *Journal of Animal Science* **53:** 1316–1327.

Heinrichs, A.J., Rogers, G.W. and Cooper, J.B. 1992. Predicting body weight and wither height in Holstein heifers using body measurements. *Journal of Dairy Science* **75:** 3577–3581.

Herring, W.O., Williams, S.E., Bertrand, J.K., Benyshek, L.L. and Miller, D.C. 1994. Comparison of live and carcass equations predicting percentage of cutability, retail product weight and trimmable fat in beef cattle. *Journal of Animal Science* **72:** 1107–1118.

Houghton, P.L. and Turlington, L.M. 1992. Application of ultrasound for feeding and finishing animals: a review. *Journal of Animal Science* **70:** 930–941.

Keane, M.G. 1994. Productivity and carcass composition of Friesian, Meuse–Rhine–Issel (MRI) × Friesian and Belgian Blue × Friesian steers. *Animal Production* **59:** 197–208.

Keane, M.G. 2003. Beef production from Holstein–Friesian bulls and steers of New Zealand and European/American descent, and Belgian Blue × Holstein–Friesians slaughtered at two weights. *Livestock Production Science* **84:** 207–218.

Keane, M.G. and Drennan, M.J. 2008. A comparison of Friesian, Aberdeen Angus × Friesian and Belgian Blue × Friesian steers finished at pasture or indoors. *Livestock Science* **115:** 268–278.

Kempster, A.J., Cook, G.L. and Southgate, J.R. 1982. A comparison of the progeny of British Friesian dams and different sire breeds in 16- and 24-month beef production systems. 2. Carcass characteristics, and rate and efficiency of meat gain. *Animal Production* **35:** 99–111.

Klosterman, E.W. 1972. Beef cattle size for maximum efficiency. *Journal of Animal Science* **34:** 875–880.

Kress, D.D., Hauser, R.E. and Chapman, A.B. 1969. Efficiency of production and cow size in beef cattle. *Journal of Animal Science* **29:** 373–383.

Lowman, B.G., Scott, N., and Somerville, S. 1976. Condition scoring of cattle, revised edition. Bulletin No. 6. Edinburgh, UK: East of Scotland College of Agriculture.

MacNeil, M.D. 1983. Choice of a prediction equation and the use of the selected equation in subsequent experimentation. *Journal of Animal Science* **57:** 1328–1336.

Minchin, W., Buckley, F., Kenny, D.A., Monahan, F.J., Shalloo, L. and O'Donovan, M. 2009a. Effect of grass silage and concentrate based finishing strategies on cull dairy cow performance, carcass and meat quality characteristics. *Meat Science* **81:** 93–101.

Minchin, W., Buckley, F., Kenny, D.A., Monahan, F.J., Shalloo, L. and O'Donovan, M. 2009b. An evaluation of over-wintering feeding strategies prior to finishing at pasture for cull dairy cows on carcass and meat quality characteristics. *Meat Science* (Submitted).

Nelson, T.C., Short, R.E., Reynolds, W.L. and Urick, J.J. 1985. Weight, height and heart girth in Hereford and crossbred palpated and visually assigned condition scores compared with cows. *Journal of Animal Science* **60:** 363–368.

Perry, T.C. and Fox, D.G. 1997. Predicting carcass composition and individual feed requirement in live cattle widely varying in body size. *Journal of Animal Science* **75:** 300–307.

SAS. 2002. Version 9. SAS Institute Inc., Cary, NC, USA.

Sawyer, J.E., Mathis, C.P. and Davis, B. 2004. Effects of feeding strategy and age on live animal performance, carcass characteristics, and economics of short-term feeding programs for culled beef cows. *Journal of Animal Science* **82:** 3646–3653.

Smith, M.T., Oltjen, J.W., Gill, D.R., Dolezal, H.G., Kropp, J.R., McPeake, C.A. and Behrens, B.D. 1989. Ultrasound and visual appraisal as methods to account for variation in performance and carcass parameters in feedlot steers. *Oklahoma Agricultural Experiment Station Research Report*: **127:** 127–136.

Snedecor, G.W. and Cochran, W.G. 1980. "Statistical Methods", 7th Edition. Iowa State University Press, Ames, USA, pages 39–82.

Sol, J., Stelwagen, J. and Dijkhuizen, A.A. 1984. A three-year herd health and management program on thirty Dutch dairy farms. II. Culling strategy and losses caused by forced replacement of dairy cows. *Veterinary Quarterly* **6:** 149–157.

Southgate, J.R., Cook, G.L. and Kempster, A.J. 1982. A comparison of the progeny of British Friesian dams and different sire breeds in 16- and 24-month beef production systems. 1. Live weight gain and efficiency of food utilisation. *Animal Production* **34:** 155–166.

Stouffer, J.R., Perry, T.C. and Fox, D.C. 1989. New techniques for real time ultrasonic evaluations of beef cattle. *Journal of Animal Science* **67:** 120 (Abstract).

Teagasc. 2007. Management Data for Farm Planning. Data Handbook 2006/2007. Oak Park, Teagasc, Ireland.

Thompson, W.R., Theuninck, D.H., Meiske, J.C., Goodrich, R.D., Rust J.R. and Byers, F.M. 1983. Linear measurements and visual appraisal as estimators of percentage empty body fat of beef cows. *Journal of Animal Science* **56:** 755–760.

Van Arendonk, J.A.M. 1985. Studies on the replacement policies in dairy cattle. II. Optimum policy and influence of changes in production and prices. *Livestock Production Science* **14:** 101–121.

Wallace, M.A., Stouffer, J.R. and Westervelt, R.G. 1977. Relationships of ultrasonic and carcass measurements with retail yield in beef cattle. *Livestock Production Science* **4:** 153–164.

Received 21 October 2008